Attenuation of Rayleigh waves caused by rough surface scattering

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Real surfaces unavoidably possess a certain degree of roughness. The presence of this roughness becomes increasingly important in applications where the manufacturing finish is imperfect, such as for parts made using additive manufacturing techniques. Therefore, it is important to understand how guided waves are affected by the roughness of the surface area inspected. The attenuation behaviour of Rayleigh waves as they propagate over a rough surface has been extensively studied theoretically. Three distinct scattering regimes have been identified for this phenomenon – the Rayleigh (long wavelength), stochastic (long to medium wavelength) and geometric (short wavelength) regimes. Mathematical expressions describing how the attenuation coefficient varies as a function of the Rayleigh wave's frequency and the statistical parameters characterising the rough surface have previously been derived and reported by others for each scattering regime. However, experimental validation of the theoretical results has proven difficult to achieve. This study validates the existing theory using high-fidelity finite-element (FE) modelling. The use of FE modelling enables the implementation of a unified approach in the validation, as the FE models are of the same kind for all studies across the range of frequency of interest – this is contrary to the theoretical approach which requires clear distinction between the scattering regimes and different mathematical methods in each to derive the resulting expressions. We began our FE validation of the theory in two-dimensional (2D) space; in the Rayleigh and stochastic regimes, very good agreement was found between the theory and the FE modelling results, both in absolute attenuation coefficient values and in the asymptotic power relationships between the attenuation coefficient and the frequency/rough surface parameters. In the geometric regime, where the literature is more limited, some useful results were obtained by combining the FE results with dimensional analysis. Using the modelling insight which we gained from the 2D study, we extended our results to three-dimensional (3D) roughness scenarios. The 3D results again showed good agreement between the theoretical asymptotical power relationships in the Rayleigh and stochastic regimes and provided a direct validation of the asymptotic power relationship in the geometric regime. Additionally, our study retrieved results from combinations of frequencies and surface statistical parameters which are outside the current theory's region of validity, showing the ability of FE modelling to extend the existing theory, both for 2D and 3D scattering scenarios.